(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number : 0 280 412 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication of patent specification : 17.11.94 Bulletin 94/46

(51) Int. Cl.[5] : G06F 15/68

(21) Application number : 88300769.2

(22) Date of filing : 29.01.88

(54) Image processing.

(30) Priority : 27.02.87 US 19567

(43) Date of publication of application : 31.08.88 Bulletin 88/35

(45) Publication of the grant of the patent : 17.11.94 Bulletin 94/46

(84) Designated Contracting States : DE FR GB NL

(56) References cited :
EP-A- 0 153 167
COMPUTER GRAPHICS AND IMAGE PROCESSING, vol. 15, no. 4, April 1981, pages 380-389, Academic Press, Inc, New York, US; J.-S. LEE: "Refined filtering of imagenoise using local statistics"

(56) References cited :
IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE, vol. PAMI-2,no. 2, March 1980, pages 165-168, IEEE, New York, US; J.-S. LEE: "Digital imageenhancement and noise filtering by use of local statistics"
PROCEEDINGS OF THE 8TH INTERNATIONAL CONFERENCE ON PATTERN RECOGNITION, Paris,27th - 31st October 1986, pages 981-983, IEEE, New York, US; W. DEMIN et al.:"A weighted averaging method for image smoothing"

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EP 0 280 412 B1

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Description

This invention relates to image processing. It finds particular application in conjunction with image enhancement, image smoothing, and other image improvement techniques for magnetic resonance images and will be described with particular reference thereto. It is to be appreciated, however, that the present invention is also applicable to improving digital x-ray images, computed tomographic images, nuclear camera images, positron emission scanners, and the like.

Techniques capable of producing images of the internal structure of a body, such as are required for example, for medical diagnostic purposes, have commonly been subject to image degradation from noise, system imperfections, and the like. Various image processing techniques have been utilized to remove the effects of the noise. See for example, "Digital Image Enhancement: A survey" Wang, et al., Computer Vision, Graphics, and Image Processing, Vol. 24, pages 363-381 (1983). In one technique, each pixel was adjusted in accordance with the mean of surrounding pixels and the variance or difference between the surrounding pixels. Each filter enhanced pixel value g'(i,j) was a weighted average of the local mean and variance values:

$$g'(i,j) = \bar{g}(i,j) + k[g(i,j) - \bar{g}(i,j)] \quad (1),$$

where $\bar{g}(i,j)$ was the local mean, $g(i,j)-\bar{g}(i,j)$ was the variance, and k was a constant that weighted the relative contributions therebetween. It is to be appreciated that when k was set larger than 1, the variance or difference between the local mean value, hence the contribution of the measured gray scale level of the pixel (i,j) was magnified. As k was set smaller, the image was smoothed or blurred as if acted upon by a low-pass filter. At the extreme at which k was set equal to zero, each pixel value was replaced by the local mean of the neighboring pixel values.

One of the drawbacks in this technique resided in selecting an appropriate value for the weighting factor k. The smaller k was set, the more the image was blurred and the more difficult it became to withdraw accurate diagnostic information. As k was set larger, edges and fine details, including noise, became enhanced. Frequently, in a medical image, the selected weighting factor k was too large for some regions and too small for other regions.

"Digital Image Processing by Use of Local Statistics" by J.S. Lee, Naval Research Laboratory, Washington, D.C. (1980), recognized that a different weighting factor k could be selected for each pixel to be enhanced. Specifically, Lee suggested setting the k for each pixel equal to the square root of the ratio of a preselected desirable local variance to the actual local variance of the selected pixel. Although the Lee pixel variable weighting factor achieved better resultant images than the constant weighting factor, there was still room for improvement.

It is an object of the present invention to provide a method of and apparatus for imaging utilising a novel technique for image improvement.

In accordance with one aspect of the present invention there is provided a method of imaging comprising: collecting image data; converting the collected data into an electronic image representation which includes an array of pixel values; for each pixel value determining (i) a variance between the pixel value and neighboring pixel values and (ii) an average of the neighboring pixel values; and replacing each pixel value of the array by a weighted combination of the said pixel value and the average of pixel values neighboring said pixel value; characterised in that the method further includes determining noise statistics of the collected data; and in that the weighting is in accordance with the determined noise statistics and the variance between said pixel value and its neighboring pixel values.

In accordance with another aspect of the present invention there is provided an imaging apparatus comprising: data generating apparatus for generating image data indicative of at least a selected region of a body; a data memory means for storing image data from the data generating apparatus; a transform means for converting the data from the data memory means into an electronic image representation which includes an array of pixel values; an average pixel value determining means for determining an average pixel value of pixel values neighboring each pixel value; and combining means for adjusting each pixel value, in accordance with the corresponding said average pixel value; characterised in that the apparatus further includes a data noise statistic determining means for determining a noise statistic from the data stored in said data memory means; and in that said combining means combines each pixel value with the corresponding average pixel value and the data noise statistic.

A first advantage of the present invention is that it provides a highest appropriate filtering level for each individual image. Because the filter function is image noise dependent, more noise free images are not overfiltered or blurred unnecessarily.

Another advantage of the present invention is that it is regionally adaptive. That is, noisier regions of the image are filtered more than regions of each image with less noise.

Other advantages of the present invention reside in an improved technique for determining image wide

noise, in achieving an improved signal-to-noise ratio without a loss of spatial resolution, and in an improved technique for determining image noise before image reconstruction.

Still further advantages of the present invention will become apparent to those of ordinary skill in the art upon reading and understanding the following detailed description of the preferred embodiment.

One method and apparatus in accordance with the invention will now be described, by way of example, with reference to the accompanying drawing which is a diagrammatic illustration of a medical diagnostic imaging apparatus in accordance with the present invention.

Referring to the drawing, the apparatus A generates medical diagnostic data which is reconstructed by an imager into an electronic image representation. An adaptive filter circuit operates on the electronic image representation to improve the image quality and viewability thereof.

Although a magnetic resonance imager is illustrated, the medical diagnostic apparatus A may be a computerized tomographic scanner, a digital x-ray apparatus, a positron emission scanner, a nuclear camera, or other diagnostic apparatus which generates data that is able to be reconstructed into an image representative of a region of an examined patient or subject. The illustrated magnetic resonance imager includes a field control means 10 which controls a main, homogeneous polarizing magnetic field through an image region generated by electromagnets 12. The field control means 10 also controls gradient magnetic fields created across the image region by gradient field coils 14 to provide spatial encoding, phase encoding, and slice select gradients. The field control means 10 further generates radio frequency electromagnetic excitation signals which are applied to radio frequency coils 16 to excite resonance of dipoles in the image region. A central computer 18 controls the relative timing and strengths of the gradient and radio frequency electromagnetic fields.

Magnetic resonance signals generated by resonating dipoles in the image region are received by the radio frequency coils and conveyed to a radio frequency receiver 20. The radio frequency receiver 20 demodulates the received signals which are converted from analog to digital format by an A/D converter 22. The digital format magnetic resonance medical diagnostic data is supplied to the imager.

The imager under control of the central computer 18 reconstructs the medical diagnostic data into an electronic image representation. More specifically, the imager reconstructs the diagnostic data which has minor noise components into an array of digital pixel values which are degraded by the noise. Each pixel value corresponds to a preselected subregion of the image region, conventionally a corresponding voxel or cubic subregion of an imaged slice. The imager includes a diagnostic data memory 30 which strores the diagnostic data from the A/D converter 22. The diagnostic data from magnetic resonance echoes are reconstructed into a single image representation. More specific to the preferred embodiment, each echo signal or view is converted into a line of ditigal values for a data matrix d(x,y). With Gaussian noise as is found in a magnetic resonance imager, each data matrix value is the sum of a data component and a noise component.

The diagnostic data memory 30 stores the diagnostic data in the data matrix format until a sufficient amount of data is received for a complex two dimensional Fourier transform means or routine 32 to transform the received data into a real image representation for storage in a real image memory 34 and an imaginary image representation for storage in an imaginary image memory 36. The sum of a data matrix value and Gaussian noise, $d(x,y)+n_g$, Fourier transforms linearly into the sum of an image pixel value and Gaussian noise, $I(i,j)+n'_g$. An image select means 38 transfers either real, imaginary, or magnitude pixel values as may be selected by the operator to the filtering means. If the real image is selected, the contents of the real image memory 34 are transferred. If the imaginary image is selected, the contents of the imaginary memory 36 are transferred. The real and imaginary images again have a Gaussian noise distribution. If a magnitude image is selected, an array of magnitude pixel values is transferred. Each magnitude pixel value is set equal to the square root of the sum of the squares of the corresponding real and imaginary image pixel values, i.e. $(I\,(\text{real})^2 + I(\text{imaginary})^2)^{1/2}$. The magnitude image has a Rayleigh noise distribution.

The algorithm implemented by the reconstruction means is, of course, selected in accordance with the medical diagnostic apparatus selected. For other diagnostic imagers, other known transform and reconstruction techniques are selected.

The filtering circuit includes an image noise level determining means 40 which calculates a value V(noise) which is indicative of the noise level of the diagnostic data or the overall image. In magnetic resonance and many other applications, the diagnostic data stored in memory 30 has substantially signal-independent, uncorrelated additive noise. This enables image noise statistics to be determined from the data noise statistics. In magnetic resonance imaging in which the diagnostic data is a Fourier transform of the image, the noise is primarily signal-independent, uncorrelated, and additive.

The noise statistics of the data are readily determined from an area of the data which contains no diagnostic data or signal, merely noise. In some applications, such a region may be created artificially by appropriate placement of the patient, inclusion of phantom or phantom regions, adjustment of the imaging sequence, or the like. However, in conventional Fourier transform magnetic resonance imaging, the majority of the signal

is concentrated in the center of the data matrix d(x,y) stored in memory 30. Accordingly, the probability of finding a signal-free region is greatest around the periphery of the data matrix. In the preferred embodiment, the data around the periphery of the data matrix is examined for uniformity. The most uniform region is assumed to be a region with substantially no signal, just noise. The degree of non-uniformity in this region is utilized as the indicator of overall image noise.

A matrix addressing means 42 serially addresses each of a plurality of preselected data matrix points (x,y) around the periphery of the data matrix. At each matrix point, a variance means 44 determines the variance V(x,y) between the data values corresponding to the addressed matrix point and its neighboring matrix points. In the preferred embodiment, the noise at each point V(x,y) is determined from the equation:

$$V(x,y) = \frac{1}{(2a+1)(2b+1)} \sum_{\ell=x-a}^{x+a} \sum_{k=y-b}^{y+b} [d(\ell,k)-\bar{d}(x,y)]^2 \qquad (2),$$

where $d(\ell,k)$ represents the data values surrounding the matrix point (x,y) and $\bar{d}(x,y)$ is the average of data values surrounding the data point d(x,y). Each local data variance V(x,y) is compared by a comparing means 46 with a previously measured variance stored in a memory 48. The smaller of the two variances is returned to the memory 48 and stored for the next comparison. In this manner, the neighborhood of the data matrix with the least signal is determined. For Gaussian noise, the noise variance is equal to the sqaure of standard deviation for Gaussian noise σ_g^2.

In the preferred embodiment, the data matrix variance determining means 44 includes a means 50 for serially receiving the data value from each point surrounding matrix point (x,y), and an averaging means 52 for determining the average of the neighboring data values. The neighboring points are again addressed serially. A subtraction means 54 determines the difference between each neighboring point data value and the average. A squaring means 56 squares the difference and a summation means 58 sums the sqaure of the difference with the accumulated sum in a cumulative memory 60. The weighting means 62 adjusts the sum by a constant to compensate for the size of the neighborhood or the like.

The filtering means further includes a first pixel memory 70 which receives pixel values P(i,j) from the reconstruction means. As discussed above, the pixel values may be the real image pixel values, the imaginary image pixel values or the magnitude image pixel values.

A pixel value average or mean determining means 72 determines the mean or average of pixel values surrounding each pixel (i,j) of the pixel memory 70. In the preferred embodiment, the pixel mean value P(i,j) is determined in accordance with:

$$\bar{P}(i,j) = \frac{1}{(2n+1)(2m+1)} \sum_{\ell=i-n}^{i+n} \sum_{k=j-m}^{j+m} P(\ell,k) \qquad (3).$$

where the values of the constants n and m indicate the size of the neighborhood.

A pixel value variance determining means 74 determines the variance V(i,j) corresponding to the neighborhood around each pixel (i,j). In the preferred embodiment, the variance is determined in accordance with:

$$V(i,j) = \frac{1}{(2n+1)(2m+1)} \sum_{\ell=i-n}^{i+n} \sum_{k=j-m}^{j+m} [P(\ell,k)-\bar{P}(i,j)]^2 \qquad (4).$$

A data noise to image noise converting means 76 converts the Gaussian data noise variance to an image noise variance V(noise). For Gaussian image noise, the image noise variance is equal to the data noise variance. For Rayleigh image noise, the image noise variance is equal to the Gaussian data noise variance times the constant $(2-\pi/2)$. For other image noise distributions, the data noise may be operated on by other constants or functions.

A weighting factor determining means 78 determines a weighting factor G(i,j) corresponding to each pixel

location in accordance with the corresponding pixel variance V(i,j) and the image noise level V(noise). In the preferred embodiment, the weighting factor is determined in accordance with:

$$G(i,j) = \frac{V(i,j)}{V(i,j) + V(noise)} \quad (5).$$

In most instances, the noise variance V(noise) will be less than or equal to the local variance V(i,j). When the noise variance of the image is very low, the weighting factor approaches one. As the noise variance increases toward the local variance, the weighting factor becomes smaller approaching one half. If the local variance is less than the noise variance, the weighting factor will become less than one-half and approach zero.

It must be noted that the noise variance is individually selected for each image and is normally different from image to image. Thus, the weighting factor at pixels in two images with the same local variance is commonly different due to the different noise variance of the two images. Optionally, other weighting factors which weight in accordance with both the local variance and the image noise variance may be selected.

A mean noise determining means 80 determines the mean magnitude of the image noise correction value $\bar{n}$. A Gaussian noise distribution has a zero mean magnitude, whereas a Rayleigh distribution does not. When a real, imaginary or other image with a Gaussian noise distribution is being processed, the mean noise is zero, i.e. $\bar{n}=0$. When a magnitude or other image with a Rayleigh noise distribution is being processed, the mean noise n is:

$$n = \left(\frac{\pi}{2}\right)^{1/2} \sigma_g$$

Other mean noise values can be calculated for other noise distributions as is known in the art.

A first subtraction means 82 subtractively combines each pixel value, P(i,j) with the corresponding average neighborhood pixel value, $\bar{P}(i,j)$. A multiplying means 84 multiplies the difference of the pixel and neighborhood values by the weighting factor corresponding to the same pixel G(i,j). An adding means 86 adds the corresponding neighborhood average to the weighted difference. A second subtracting means 88 subtracts the mean noise correction value from the sum. This sum is stored in a filtered image memory 90 and displayed on a video monitor or other display means 92. That is, each filtered pixel value P*(i,j) is equal to:

$$P^*(i,j) = \bar{P}(i,j) + \frac{V(i,j)[P(i,j) - \bar{P}(i,j)]}{V(i,j) + V(noise)} - n \quad (7).$$

With this relationship, with less data noise variance, the corresponding pixel value P(i,j) is weighted most heavily. Similarly, in a local region with alot of variance, the actual pixel value is again weighted heavily so as not to blur the local resolution. However, in images that are very noisy or in regions that are very uniform, the neighborhood average is weighted more heavily.

The invention has been described with reference to the preferred embodiment. Obviously, modifications and alterations will occur to others upon reading and understanding the preceding detailed description. It is intended that the invention be construed as including all such alterations and modifications insofar as they come within the scope of the appended claims or the equivalents thereof.

Claims

1. A method of imaging comprising: collecting image data; converting the collected data into an electronic image representation which includes an array of pixel values; for each pixel value determining (i) a variance between the pixel value and neighboring pixel values and (ii) an average of the neighboring pixel values; and replacing each pixel value of the array by a weighted combination of the said pixel value and the average of pixel values neighboring said pixel value; characterised in that the method further includes determining noise statistics of the collected data; and in that the weighting is in accordance with the determined noise statistics and the variance between said pixel value and its neighboring pixel values.

2. A method according to Claim 1 wherein the noise statistics of the collected data are determined by: digitizing the collected data and storing the digitized data in a data memory; determining a data variance between each of a plurality of data values stored in the data memory and its neighboring data values; and comparing each determined data variance with previously determined data variances to determine a minimum data variance, the minimum data variance being indicative of the noise statistics, whereby the noise variance of the collected diagnostic data is determined.

3. A method according to Claim 2 wherein the data variance is determined only for selected data values whose surrounding data values have a higher probability of representing substantially no signal such that the data variance is primarily indicative of noise variance rather than imaged structure.

4. A method according to Claim 2 or Claim 3 further including: generating the data with a magnetic resonance imager; organizing the digitized data values in the data memory in a rectangular matrix array; and, in the noise variance determination, determining the variance of data values disposed generally around the periphery of the matrix.

5. A method according to any one of the preceding claims wherein the weighting is proportional to the ratio of the corresponding data value variance to a sum of the corresponding pixel value variance and the determined noise statistics.

6. A method according to any one of the preceding claims wherein the replacing step includes subtractively combining replaced pixel values with the average of neighboring pixel values and multiplying the difference with a weighting function, the weighting function being determined in accordance with the determined noise statistics and the pixel value variance between the replaced pixel and its neighboring pixel values.

7. A method according to Claim 6 wherein the weighting function is proportional to a ratio of the pixel value variance corresponding to the replaced pixel and the determined noise statistics.

8. A method according to Claim 7 wherein the replacing step further includes summing the average of pixel values neighboring the replaced pixel value with the product of said difference and said weighting function.

9. A method according to Claim 8 further including: determining a mean noise level value from the determined noise statistics; and wherein the replacing step further includes subtracting the mean noise level value from said weighted combination.

10. An imaging apparatus comprising: data generating apparatus (A) for generating image data indicative of at least a selected region of a body; a data memory means (30) for storing image data from the data generating apparatus (A); a transform means (32, 34, 36) for converting the data from the data memory means (30) into an electronic image representation which includes an array of pixel values; an average pixel value determining means (38, 70, 72) for determining an average pixel value of pixel values neighboring each pixel value; and combining means (82, 84, 86, 88) for adjusting each pixel value, in accordance with the corresponding said average pixel value; characterised in that the apparatus further includes a data noise statistic determining means (40, 76) for determining a noise statistic from the data stored in said data memory means (30); and in that said combining means (82, 84, 86, 88) combines each pixel value with the corresponding average pixel value and the data noise statistic.

11. An apparatus according to Claim 10 further including:
a variance determining means (74) for determining a variance between each pixel value and its neighboring pixel values; a weighting function determining means (78) for determining a weighting function for each pixel value in accordance with (i) a data noise level from the noise statistic determining means (40, 76) and (ii) the variance corresponding to the same pixel value; and wherein the combining means (82, 84, 86, 88) weights a combination of each pixel value and the corresponding average pixel value with the weighting function.

12. An apparatus according to Claim 10 or Claim 12 wherein the combining means (82, 84, 86, 88) includes: a subtraction means (82) for subtractively combining each pixel value with its corresponding average of neighboring pixel values; means for weighting (84) the difference from the subtractive combining means with the weighting factor; and an adding means (86) for combining the corresponding average of neighboring pixel values with the weighted difference.

13. An apparatus according to any one of Claims 10 to 12 further including: an analog-to-digital converter (22) for digitizing the image data; and wherein the data memory means (30) stores the digitized data in a rectangular matrix array.

14. An apparatus according to Claim 13 wherein the image data generating apparatus (A) is a magnetic resonance imager (A); wherein the digital data values around a periphery of the rectangular matrix array tend to have a smaller signal contribution; and further including: a data memory addressing means (42) for addressing the data values around the periphery of the matrix; a data variance determining means (44)

for determining a data value variance between each addressed matrix value and its neighboring matrix values; and a comparing means (46, 48) for comparing each determined data value variance of previously addressed data points, the smallest of the determined data value variances being the data noise statistic, the comparing means (46, 48) being operatively connected with the combining means (82, 84, 86, 88) for supplying the smallest data value variance thereto.

15. An apparatus according to any one of Claims 10 to 14 further including: a mean image noise determining means (80) for determining a mean image noise value from the output of the data noise statistic means (40, 76); and wherein the combining means (82, 84, 86, 88) subtracts the mean image noise value from the combination of each pixel value and the corresponding average pixel value.

16. An apparatus according to any one of Claims 10 to 15 further including an image memory (90) connected with the combining means (82, 84, 86, 88) for storing the adjusted pixel values produced thereby.

Patentansprüche

1. Abbildungsverfahren, umfassend: Erfassen von Bilddaten; Umsetzen der erfaßten Daten in eine elektronische Bildrepräsentation, die ein Feld aus Pixelwerten umfaßt; Bestimmen für jeden Pixelwert eine Varianz (i) zwischen dem Pixelwert und benachbarten Pixelwerten und (ii) einen Durchschnittswert der benachbarten Pixelwerte; und Ersetzen jedes Pixelwerts des Feldes durch eine gewichtete Kombination dieses Pixelwerts und des Durchschnitts von Pixelwerten, die diesem Pixelwert benachbart sind;
dadurch gekennzeichnet,
daß das Verfahren ferner die Ermittlung von Rauschstatistiken der erfaßten Daten umfaßt; und daß die Wichtung gemäß den ermittelten Rauschstatistiken und der Varianz zwischen dem Pixelwert und dessen Nachbarpixelwerten ist.

2. Verfahren nach Anspruch 1, in welchem die Rauschstatistiken der erfaßten Daten bestimmt werden durch: Digitalisieren der erfaßten Daten und Speichern der digitalisierten Daten in einem Datenspeicher; Ermitteln einer Datenvarianz zwischen jedem mehrerer Datenwerte, die im Datenspeicher gespeichert sind, und dessen benachbarten Datenwerten; und Vergleichen jeder ermittelten Datenvarianz mit zuvor ermittelten Datenvarianzen zur Ermittlung einer minimalen Datenvarianz, wobei die minimale Datenvarianz die Rauschstatistiken anzeigt, wodurch die Rauschvarianz der erfaßten Diagnosedaten ermittelt wird.

3. Verfahren nach Anspruch 2, in welchem die Datenvarianz nur für selektierte Datenwerte ermittelt wird, deren umgebende Datenwerte eine höhere Wahrscheinlichkeit aufweisen, im wesentlichen kein Signal darzustellen, derart, daß die Datenvarianz primär eine Rauschvarianz statt eine abgebildete Struktur anzeigt.

4. Verfahren nach Anspruch 2 oder 3, ferner umfassend: Erzeugen der Daten mit einem Magnetresonanz-Abbildungsgerät; Vornehmen eines organisatorischen Aufbaus der digitalisierten Datenwerte im Datenspeicher in einer rechteckigen Matrixanordnung; und Ermitteln der Varianz von Datenwerten bei der Rauschvarianzermittlung, die im wesentlichen um den Umfangsbereich der Matrix angeordnet sind.

5. Verfahren nach einem der vorhergehenden Ansprüche, in welchem die Wichtung proportional zum Verhältnis der entsprechenden Datenwertvarianz zu einer Summe der entsprechenden Pixelwertvarianz und der ermittelten Rauschstatistiken ist.

6. Verfahren nach einem der vorhergehenden Ansprüche, in welchem der ersetzende Schritt die subtraktive Kombination ersetzter Pixelwerte mit dem Durchschnittswert benachbarter Pixelwerte und die Multiplikation der Differenz mit einer Wichtungsfunktion umfaßt, wobei die Wichtungsfunktion entsprechend den ermittelten Rauschstatistiken und der Pixelwertvarianz zwischen dem ersetzten Pixel und dessen Nachbarpixelwerten ermittelt wird.

7. Verfahren nach Anspruch 6, in welchem die Wichtungsfunktion proportional zu einem Verhältnis der Pixelwertvarianz entsprechend dem ersetzten Pixel und den ermittelten Rauschstatistiken ist.

8. Verfahren nach Anspruch 7, in welchem der ersetzende Schritt ferner die Summierung des Durchschnitts-

werts von Pixelwerten, die dem ersetzten Pixelwert benachbart sind, zum Produkt der Differenz und der Wichtungsfunktion umfaßt.

9. Verfahren nach Anspruch 8, ferner aufweisend: Ermitteln eines mittleren Rauschpegelwerts aus den ermittelten Rauschstatistiken; und in welchem der ersetzende Schritt ferner die Subtraktion des mittleren Rauschpegelwerts von der gewichteten Kombination umfaßt.

10. Abbildungsvorrichtung, aufweisend: eine Datenerzeugungsvorrichtung (A) zum Erzeugen von Bilddaten, die zumindest eine selektierte Region eines Körpers anzeigen; eine Datenspeichereinrichtung (30) zum Speichern von Bilddaten von der Datenerzeugungsvorrichtung (A); eine Transformationseinrichtung (32, 34, 36) zum Umsetzen der Daten aus der Datenspeichereinrichtung (30) in eine elektronische Bildrepräsentation, die ein Feld aus Pixelwerten umfaßt; eine Durchschnittspixelwert-Ermittlungseinrichtung (38, 70, 72) zum Ermitteln eines durchschnittlichen Pixelwerts von Pixelwerten, die jedem Pixelwert benachbart sind; und eine Kombinationseinrichtung (82, 84, 86, 88) zur Einstellung jedes Pixelwerts gemäß dem entsprechenden solchen Durchschnittspixelwert;
dadurch gekennzeichnet,
daß die Vorrichtung ferner eine Datenrauschstatistik-Ermittlungseinrichtung (40, 76) aufweist, die eine Rauschstatistik aus den in der Speichereinrichtung (30) gespeicherten Daten ermittelt; und daß die Kombinationseinrichtung (82, 84, 86, 88) jeden Pixelwert mit dem entsprechenden Durchschnittspixelwert und der Datenrauschstatistik kombiniert.

11. Vorrichtung nach Anspruch 10, ferner aufweisend: eine Varianzermittlungseinrichtung (74) zum Ermitteln einer Varianz zwischen jedem Pixelwert und dessen benachbarten Pixelwerten; eine Wichtungsfunktions-Ermittlungseinrichtung (78) zum Ermitteln einer Wichtungsfunktion für jeden Pixelwert gemäß (i) einem Datenrauschpegel von der Rauschstatistik-Ermittlungseinrichtung (40, 76) und (ii) der Varianz entsprechend demselben Pixelwert; und in welcher die Kombinationseinrichtung (82, 84, 86, 88) eine Kombination jedes Pixelwerts und des entsprechenden Durchschnittspixelwerts mit der Wichtungsfunktion wichtet.

12. Vorrichtung nach Anspruch 10 oder Anspruch 12, in welcher die Kombinationseinrichtung (82, 84, 86, 88) umfaßt: eine Subtraktionseinrichtung (82) zur subtraktiven Kombination jedes Pixelwerts mit seinem entsprechenden Durchschnittswert von benachbarten Pixelwerten; eine Einrichtung zum Wichten (84) der Differenz von der subtraktiven Kombinationseinrichtung mit dem Wichtungsfaktor; und eine Additionseinrichtung (86) zur Kombination des entsprechenden Durchschnittswerts benachbarter Pixelwerte mit der gewichteten Differenz.

13. Vorrichtung nach einem der Ansprüche 10 bis 12, ferner aufweisend: einen Analog/Digital-Wandler (22) zur Digitalisierung der Bilddaten; und in welcher die Datenspeichereinrichtung (30) die digitalisierten Daten in einem rechteckigen Matrixfeld speichert.

14. Vorrichtung nach Anspruch 13, in welcher die Bilddatenerzeugungseinrichtung (A) ein Magnetresonanz-Abbildungsgerät (A) ist; in welcher die digitalen Datenwerte um einen Umfang des rechteckigen Matrixfeldes dazu neigen, einen geringeren Signalbeitrag aufzuweisen; und ferner aufweisend: eine Datenspeicheradressierungseinrichtung (42) zum Adressieren der Datenwerte um den Umfang der Matrix; eine Datenvarianzermittlungseinrichtung (44) zum Ermitteln einer Datenwertvarianz zwischen jedem adressierten Matrixwert und seinen benachbarten Matrixwerten; und eine Vergleichseinrichtung (46, 48) zum Vergleichen jeder ermittelten Datenwertvarianz zuvor adressierter Datenpunkte, wobei die geringste der ermittelten Datenwertvarianzen die Datenrauschstatistik (Kenngröße) ist, wobei die Vergleichseinrichtung (46, 48) betriebswirksam mit der Kombinationseinrichtung (82, 84, 86, 88), um dieser die geringste Datenwertvarianz zuzuführen, verbunden ist.

15. Vorrichtung nach einem der Ansprüche 10 bis 14, ferner aufweisend: eine Bildrauschmittelwert-Ermittlungseinrichtung (80) zum Ermitteln eines mittleren Bildrauschwerts aus dem Ausgangssignal der Datenrauschstatistikeinrichtung (40, 76); und in welcher die Kombinationseinrichtung (82, 84, 86, 88) den mittleren Bildrauschwert von der Kombination jedes Pixelwerts und des entsprechenden Durchschnitspixelwerts subtrahiert.

16. Vorrichtung nach einem der Ansprüche 10 bis 15, ferner aufweisend einen Bildspeicher (90), der mit der Kombinationseinrichtung (82, 84, 86, 88) verbunden ist und die hierdurch erzeugten eingestellten Pixel-

werte speichert.

Revendications

1. Procédé de formation d'image, comprenant la collecte de données d'image, la conversion des données d'image en une représentation électronique d'image qui comprend une matrice de valeurs d'éléments d'image, et, pour chaque valeur d'élément d'image, la détermination (i) d'une variance entre la valeur de l'élément d'image et les valeurs des éléments d'image voisins, et (ii) d'une moyenne des valeurs des éléments d'image voisins, et le remplacement de chaque valeur d'élément d'image de la matrice par une combinaison pondérée de la valeur de l'élément d'image et de la moyenne des valeurs d'éléments d'image voisins de la valeur de l'élément d'image, caractérisé en ce que le procédé comporte en outre la détermination de la statistique de bruit des données collectées, et en ce que la pondération s'effectue suivant la statistique de bruit déterminée et la variance entre la valeur de l'élément d'image et les valeurs des éléments d'image voisins de celui-ci.

2. Procédé selon la revendication 1, dans lequel la statistique de bruit des données collectées est déterminée par numérisation des données collectées et mémorisation des données numérisées dans une mémoire de données, détermination d'une variance des données entre chacune de plusieurs valeurs de données conservées dans la mémoire de données et les valeurs des données voisines, et comparaison de chaque variance des données déterminée à des variances de données déterminées précédemment pour la détermination d'une variance minimale des données, la variance minimale des données étant représentative de la statistique de bruit, si bien que la variance du bruit des données collectées de diagnostic est déterminée.

3. Procédé selon la revendication 2, dans lequel la variance des données n'est déterminée que pour des valeurs choisies de données dont les valeurs des données environnantes ont une grande probabilité de représenter pratiquement l'absence de signal, si bien que la variance des données est essentiellement représentative de la variance du bruit plutôt que de la structure de l'image.

4. Procédé selon la revendication 2 ou 3, comprenant en outre la création de données avec un appareil de formation d'image par résonance magnétique, l'organisation des valeurs numérisées de données dans la mémoire de données sous forme d'une matrice rectangulaire et, au cours de la détermination de la variance de bruit, la détermination de la variance des valeurs de données disposées de façon générale à la périphérie de la matrice.

5. Procédé selon l'une quelconque des revendications précédentes, dans lequel la pondération est proportionnelle au rapport de la variance de la valeur des données correspondantes et d'une somme de la variance de la valeur de l'élément d'image correspondant et de la statistique de bruit qui est déterminée.

6. Procédé selon l'une quelconque des revendications précédentes, dans lequel l'étape de remplacement comprend la combinaison par soustraction des valeurs des éléments d'image qui sont remplacées par la moyenne des valeurs d'éléments d'image voisins et par multiplication de la différence par une fonction de pondération, la fonction de pondération étant déterminée d'après la statistique de bruit déterminée et la variance de la valeur de l'élément d'image entre l'élément d'image remplacé et les valeurs des éléments d'image voisins.

7. Procédé selon la revendication 6, dans lequel la fonction de pondération est proportionnelle à un rapport de la variance de la valeur de l'élément d'image correspondant à l'élément d'image remplacé et de la statistique de bruit déterminée.

8. Procédé selon la revendication 7, dans lequel l'étape de remplacement comporte en outre la sommation de la moyenne des valeurs d'éléments d'image voisins de la valeur de l'élément d'image remplacé par le produit de la différence et de la fonction de pondération.

9. Procédé selon la revendication 8, comprenant en outre la détermination de la valeur d'un niveau moyen de bruit tirée de la statistique de bruit déterminée, et dans lequel l'étape de remplacement comporte en outre la soustraction de la valeur du niveau moyen de bruit de la combinaison pondérée.

10. Appareil de formation d'image comprenant un appareil (A) générateur de données d'image représentatives d'au moins une région choisie d'un corps, un dispositif (30) à mémoire de données destiné à conserver les données d'image provenant de l'appareil (A) générateur de données, un dispositif (32, 34, 36) de transformation qui convertit les données du dispositif (30) à mémoire de données en une représentation électronique d'image qui comprend une matrice de valeurs d'éléments d'image, un dispositif (38, 70, 72) de détermination d'une valeur moyenne d'élément d'image des valeurs des éléments d'image voisins de chaque valeur d'élément d'image, et un dispositif (82, 84, 86, 88) de combinaison destiné à ajuster chaque valeur d'élément d'image d'après la valeur moyenne correspondante d'élément d'image, caractérisé en ce que l'appareil comporte en outre un dispositif (40, 76) de détermination d'une statistique de bruit des données destiné à déterminer une statistique de bruit à partir des données conservées dans le dispositif (30) à mémoire de données, et en ce que le dispositif de combinaison (82, 84, 86, 88) combine chaque valeur d'élément d'image à la valeur moyenne correspondante d'élément d'image et à la statistique de bruit des données.

11. Appareil selon la revendication 10, comprenant en outre un dispositif (74) de détermination d'une variance entre chaque valeur d'élément d'image et les valeurs des éléments d'image voisins, un dispositif (78) de détermination d'une fonction de pondération pour chaque valeur d'élément d'image d'après (i) un niveau de bruit de données provenant du dispositif (40, 76) de détermination d'une statistique de bruit, et (ii) la variance correspondant à la même valeur d'élément d'image, et dans lequel le dispositif de combinaison (82, 84, 86, 88) pondère une combinaison de chaque valeur d'élément d'image et de la valeur moyenne correspondante d'élément d'image à la fonction de pondération.

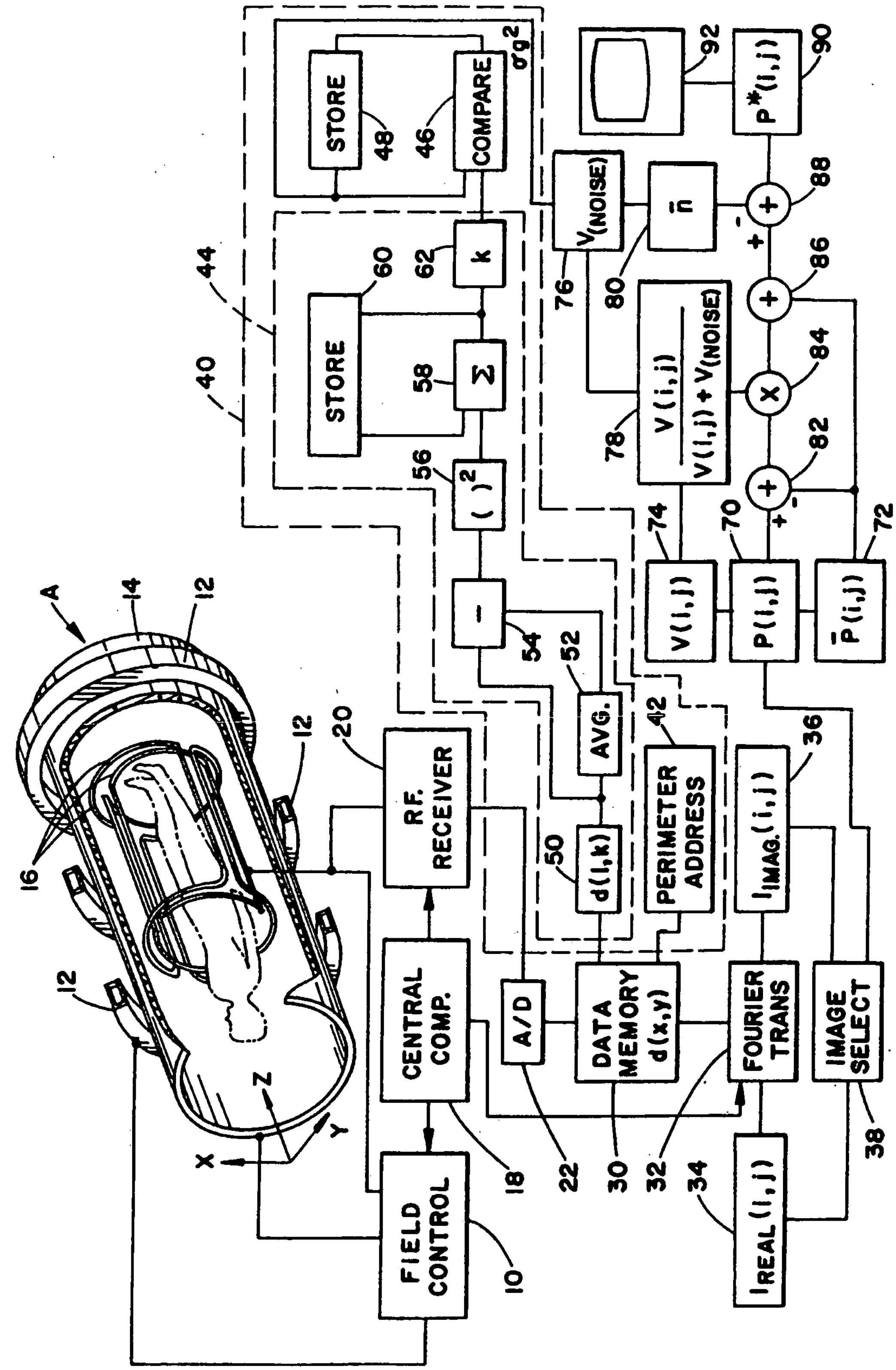
12. Appareil selon la revendication 10 ou 11, dans lequel le dispositif de combinaison (82, 84, 86, 88) comprend un dispositif (82) de soustraction destiné à combiner de manière soustractive chaque valeur d'élément d'image et la moyenne correspondante des valeurs des éléments d'image voisins, un dispositif (84) de pondération de la différence provenant du dispositif de combinaison par soustraction à l'aide du facteur de pondération, et un dispositif additionneur (86) destiné à combiner la moyenne correspondante des valeurs des éléments d'image voisins à la différence pondérée.

13. Appareil selon l'une quelconque des revendications 10 à 12, comprenant en outre un convertisseur analogique-numérique (22) destiné à numériser les données d'image, et dans lequel le dispositif (30) à mémoire de données conserve les données numérisées sous forme d'une matrice rectangulaire.

14. Appareil selon la revendication 13, dans lequel l'appareil (A) générateur des données d'image est un appareil (A) de formation d'image par résonance magnétique, dans lequel les valeurs des données numériques placées à la périphérie de la matrice rectangulaire ont tendance à présenter une plus petite contribution au signal, et comprenant en outre un dispositif (42) d'adressage de mémoire de données destiné à adresser les valeurs des données à la périphérie de la matrice, un dispositif (44) de détermination d'une variance de la valeur des données entre chaque valeur adressée de la matrice et les valeurs voisines de la matrice, et un dispositif (46, 48) de comparaison de chaque variance déterminée pour une valeur de données pour les points de données antérieurement adressés, la plus petite des variances déterminée pour les valeurs de données étant la statistique de bruit des données, le dispositif de comparaison (46, 48) étant connecté pendant le fonctionnement au dispositif de combinaison (82, 84, 86, 88) afin qu'il transmette la plus petite variance de valeur de données au dispositif de comparaison.

15. Appareil selon l'une quelconque des revendications 10 à 14, comprenant en outre un dispositif (80) de détermination de bruit moyen de l'image destiné à déterminer une valeur moyenne du bruit de l'image à partir du signal de sortie du dispositif (40, 76) de détermination de statistique de bruit des données, et dans lequel le dispositif de combinaison (82, 84, 86, 88) soustrait la valeur moyenne du bruit de l'image de la combinaison de chaque valeur d'élément d'image et de la valeur moyenne correspondante d'élément d'image.

16. Appareil selon l'une quelconque des revendications 10 à 15, comprenant en outre une mémoire (90) d'image connectée au dispositif de combinaison (82, 84, 86, 88) et destinée à mémoriser les valeurs ajustées d'éléments d'image ainsi produites.


FIELD CONTROL
CENTRAL COMP.
RF. RECEIVER
A/D
DATA MEMORY d(x,y)
FOURIER TRANS
IMAGE SELECT
I REAL (i,j)
I IMAG. (i,j)
PERIMETER ADDRESS
d(i,k)
AVG.
STORE
COMPARE
STORE
k
V(i,j)
P(i,j)
P̄(i,j)
V(NOISE)
V(i,j) / V(i,j) + V(NOISE)
n̄
P*(i,j)